DIAMOND-SURFACED FEMORAL HEAD FOR USE IN A PROSTHETIC JOINT

VI. Claims

Similar case: 09/494,277

We claim:

1. A femoral head comprising:

a sintered polycrystalline diamond compact,

a substrate located on said polycrystalline diamond compact, said substrate including a metal,

a diamond table sintered to said substrate,

a gradient transition zone between said substrate and said diamond table in said polycrystalline diamond compact, said gradient transition zone having a substrate side and a diamond table side, said gradient transition zone having both solvent-catalyst metal and diamond therein, and said gradient transition zone exhibiting a transition of ratios of percentage content of solvent-catalyst metal to diamond from one side of said gradient transition zone to another such that at a first point in said gradient transition zone near said substrate side, the ratio of percentage content of solvent-catalyst metal to diamond is greater than it is at a second point in said gradient transition zone closer to said diamond side than said first point,

chemical bonds between said diamond table and said substrate which tend to secure said diamond table to said substrate, and

a load bearing and articulation surface on said polycrystalline diamond compact, said load bearing and articulation surface including polycrystalline diamond, said load

bearing and articulation surface being formed to present a shape that is at least partially convex spherical.

2. A head as recited in claim 1 wherein diamond in said polycrystalline diamond compact has a coefficient of thermal expansion CTE_{Cd}, and wherein said substrate has a coefficient of thermal expansion CTE_{sub}, and wherein CTE_{Cd} is not equal to CTE_{sub}, wherein said diamond in said polycrystalline diamond compact has a modulus M_{Cd}, and wherein said substrate in said polycrystalline diamond compact has a modulus M_{sub}, and wherein M_{Cd} is not equal to M_{sub}.

3. A head as recited in claim 1 further comprising a mechanical grip between said diamond table and said substrate, said mechanical grip tending to secure said diamond table to said substrate.

4. A head as recited in claim 1 further comprising interstitial spaces in said diamond table.

5. A head as recited in claim 4 further comprising solvent-catalyst metal located in said diamond table interstitial spaces.

6. A head as recited in claim 1 further comprising a residual stress field in said polycrystalline diamond compact that tends to enhance the strength of said polycrystalline diamond compact.

7. A head as recited in claim 1 further comprising a crystalline diamond structure in said diamond table.

8. A head as recited in claim 1 wherein said polycrystalline diamond compact is polished to an Ra value of between about 0.5 to about 0.005 microns.

9. A head as recited in claim 1 further comprising:

a neck having a first end and a second end, said neck first end being attachable to said head,

a body, said body being attachable to said neck second end, and

a stem, said stem being attachable to said body.

10. A head as recited in claim 9 further comprising a bone mating surface on at least one of said body and said stem, said bone mating surface including a structure selected from the group consisting of metal mesh, porous metal, porous diamond, metal sintered beads, and plasma spray metal.

11. A head as recited in claim 1 further comprising:

a neck having a first end and a second end, said neck first end being attached to said head,

a body, said body being attachable to said neck second end, and

a stem, said stem being attachable to said body.

12. A head as recited in claim 11 further comprising a bone mating surface on at least one of said body and said stem.

13. A head as recited in claim 1 further comprising:

a stem for placement into a femur,

a body located adjacent said stem when said stem is installed in a patient, and

a neck located between said body and said head when installed in a patient.

14. A head as recited in claim 13 wherein at least one of said stem and body includes a bone mating surface on at least a portion of its exterior.

16. A head as recited in claim 1 wherein said substrate includes a plurality of metals.

17. A head as recited in claim 1 wherein said substrate includes a metal alloy with at least one femoral head of said metal alloy being selected from the group consisting of titanium, aluminum, vanadium, molybdenum, hafnium, nitinol, cobalt, chrome, molybdenum, tungsten, cemented tungsten carbide, cemented chrome carbide, fused silicon carbide, nickel, tantalum, and stainless steel.

18. A head as recited in claim 1 wherein said substrate includes a metal alloy selected from the group consisting of titanium, titanium aluminum and vanadium, titanium molybdenum hafnium, titanium and nitinol, cobalt chrome, cobalt chrome molybdenum, cobalt chrome tungsten, cobalt chrome cemented tungsten carbide, cobalt chrome cemented chrome carbide, fused silicon carbide and stainless steel.

19. A head as recited in claim 1 wherein said substrate includes a plurality of substrate layers.

20. A head as recited in claim 1 wherein said substrate includes at least two distinct substrate layers of different metals.

21. A head as recited in claim 1 wherein said polycrystalline diamond compact is manufactured by a high pressure and high temperature sintering process.

22. A head as recited in claim 19 wherein in said polycrystalline diamond compact, a barrier layer is present between at least two of said substrate layers.

23. A head as recited in claim 1 wherein in said polycrystalline diamond compact diamond table, at least two different sizes of diamond crystals are found.

24. A head as recited in claim 1 further comprising substrate surface topographical features on said substrate.

25. A head for use in a prosthetic joint comprising:

a generally convex spherical ball formed from substantially solid polycrystalline diamond, said polycrystalline diamond having a structure derived from its crystalline diamond form and being free of a chemical attachment to a substrate, and

a load bearing and articulation surface located on said ball, said load bearing and articulation surface being formed from polycrystalline diamond, said load bearing and articulation surface being adapted to facilitate articulation of said ball against a counter bearing surface.

26. A head as recited in claim 25 further comprising interstitial spaces in said solid polycrystalline diamond.

27. A head as recited in claim 25 further comprising solvent-catalyst metal present in said solid polycrystalline diamond interstitial spaces.

28. A head as recited in claim 26 further comprising solvent-catalyst metal located in said acetabular cup solid polycrystalline diamond interstitial spaces.

30. A cup as recited in claim 25 wherein said polycrystalline diamond load bearing and articulation surface has an Ra value of between about 0.5 to about 0.005 microns.

31. A head as recited in claim 25 wherein said polycrystalline diamond load bearing and articulation surface is burnished.

32. A head as recited in claim 25 wherein solvent-catalyst metal has been removed from said solid polycrystalline diamond.

33. A head as recited in claim 25 wherein solvent-catalyst metal has been leached from said acetabular cup solid polycrystalline diamond.

34. A head as recited in claim 25 wherein solvent-catalyst metal has been

leached form said solid polycrystalline diamond and replaced with another metal to form thermally stable diamond.

35. A head as recited in claim 25 wherein said acetabular cup head solid polycrystalline diamond includes diamond crystals of at least two different dimensions.

36. A head as recited in claim 25 further comprising:

a stem for placement into a femur,

a body located adjacent said stem when said stem is installed in a patient, and

a neck located between said body and said head when installed in a patient.

37. A head as recited in claim 25 wherein at least one of said stem and body includes a bone mating surface on at least a portion of its exterior.

38. A femoral head comprising:

a convex load bearing and articulation surface,

a biocompatible substrate material formed to provide structural support for said load bearing and articulation surface,

a volume of diamond located on said load bearing and articulation surface, said diamond being intended to permit articulation of a femoral head,

said diamond presenting a smooth and low-friction surface to facilitate femoral head articulation, and

a crystalline diamond structure in said volume of diamond.

39. A head as recited in claim 39 wherein said volume of diamond has been deposited on said substrate by chemical vapor deposition.

40. A head as recited in claim 39 wherein said volume of diamond has been deposited on said substrate by physical vapor deposition.

41. A head as recited in claim 39 wherein said volume of diamond is polycrystalline diamond.

42. A head as recited in claim 39 wherein said volume of diamond includes diamond selected from the group consisting of natural diamond, monocrystalline diamond, polycrystalline diamond, diamond created by chemical vapor deposition, and diamond created by physical vapor deposition.

43. A head as recited in claim 39 wherein said diamond surface is burnished.

44. A head as recited in claim 39 wherein said diamond surface has an Ra value of between about 0.5 to about 0.005 microns.

45. A head as recited in claim 39 wherein said volume of diamond is sintered to said substrate.

46. A head as recited in claim 39 wherein said volume of diamond and said substrate form a sintered polycrystalline diamond compact.

47. A head as recited in claim 46 wherein said sintered polycrystalline diamond compact includes a gradient transition zone between said substrate and said diamond.

48. A head as recited in claim 47 further comprising chemical bonds between said diamond and said substrate.

49. A head as recited in claim 48 further comprising a mechanical grip between said diamond and said substrate.

50. A head as recited in claim 49 further comprising substrate surface topographical features which contribute to said mechanical grip between said diamond and said substrate.

51. A femoral head comprising:

a substrate that includes a solvent-catalyst metal,

a diamond layer sintered to said substrate,

a zone between said substrate and said diamond layer that has a composition gradient of decreasing solvent-catalyst metal content across said zone,

chemical bonds in said zone, said chemical bonds including diamond-to-diamond bonds in said diamond table, diamond-to-metal bonds in said gradient transition zone, and metal-to-metal bonds in said solvent-catalyst metal.

a mechanical grip between said diamond layer and said substrate which tends to secure said diamond layer to said substrate,

interstitial spaces in said diamond layer,

solvent-catalyst metal present in said interstitial spaces, and

a non-planar load bearing and articulation surface formed by said diamond layer.

52. A femoral head as recited in claim 51 wherein sintered diamond in said diamond layer has a coefficient of thermal expansion CTE_{Cd}, and wherein said substrate has a coefficient of thermal expansion CTE_{sub}, and wherein CTE_{Cd} is not equal to CTE_{sub}.

53. A femoral head as recited in claim 51 wherein said sintered diamond in said diamond layer has a modulus $M_{Cd,}$ and wherein said substrate has a modulus M_{sub}, and wherein $M_{Cd,}$ is not equal to M_{sub}.

54. A femoral head as recited in claim 51 further comprising a residual stress field that tends to enhance the strength of attachment of said diamond layer to said substrate.

55. A femoral head as recited in claim 51 further comprising substrate surface topographical features on said substrate.

56. A femoral head as recited in claim 51 wherein said substrate includes a metal alloy with at least one femoral head of said metal alloy being selected from the group consisting of titanium, aluminum, vanadium, molybdenum, hafnium, nitinol, cobalt, chrome, molybdenum, tungsten, cemented tungsten carbide, cemented chrome carbide, fused silicon carbide, nickel, tantalum, and stainless steel.

57. A femoral head as recited in claim 51 wherein diamond layer comprises diamond feedstock that has diamond particles that have a dimension in the range of less than about 1 nanometer to more than about 100 microns.

58. A femoral head as recited in claim 51 wherein said diamond load bearing and articulation surfaces is a continuous diamond surface.

59. A femoral head as recited in claim 51 wherein said diamond load bearing and articulation surface is a discontinuous diamond surface.

60. A femoral head as recited in claim 51 wherein said diamond load bearing and articulation surface is a segmented diamond surface.

61. A femoral head as recited in claim 51 wherein a lip is present on said substrate in order to interlock said diamond layer to said substrate.

62. A femoral head as recited in claim 51 further comprising CoCr solvent-catalyst metal in said diamond table interstitial spaces.

63. A femoral head as recited in claim 51 further comprising a continuous gradient in said diamond layer.

64. A femoral head as recited in claim 51 further comprising an incremental gradient in said diamond layer.

65. A femoral head as recited in claim 64 wherein said incremental gradient includes a plurality of strata in said diamond layer, a first of said strata having characteristics which differ from those of a second strata.

66. A femoral head as recited in claim 65 wherein said differing characteristics of said strata are selected from the group consisting of diamond particle size, diamond particle distribution, and solvent-catalyst metal content.

67. A femoral head as recited in claim 51 further comprising an interface gradient.

68. A femoral head as recited in claim 51 wherein said diamond layer has a thickness of from less than about 1 micron to more than about 3000 microns.

69. A femoral head comprising:

a substrate,

a diamond layer sintered to said substrate,

interstitial spaces located in said diamond layer,

solvent-catalyst metal located in said interstitial spaces,

a zone that includes both sintered diamond and substrate, said zone having a composition gradient of solvent-catalyst metal content to diamond content, said gradient being selected from the group consisting of interface gradient, continuous gradient and incremental gradient,

chemical bonds in the femoral head, said chemical bonds including diamond-to-diamond bonds in said diamond layer, diamond-to-metal bonds in said zone, and metal-to-metal bonds in said solvent-catalyst metal,

a mechanical grip between said diamond layer and said substrate which tends to secure said diamond layer to said substrate, and

a non-planar load bearing and articulation surface formed by said diamond layer.

70. A femoral head as recited in claim 69 further comprising a lip of substrate material which serves to hold said diamond layer in place adjacent said substrate.

71. A femoral head as recited in claim 69 further comprising a dovetailed interlock between said diamond table and said substrate.

72. A femoral head as recited in claim 69 further comprising a lip on said substrate that interlocks said substrate with said diamond table.

73. A femoral head as recited in claim 69 wherein at least some of said bonds are sp3 carbon bonds.

74. A femoral head as recited in claim 69 wherein said diamond table includes a plurality of strata such that a first of said strata having characteristics which differ from those of a second strata.

75. A femoral head as recited in claim 74 wherein said differing characteristics are selected from the group consisting of diamond particle size, diamond particle distribution, and solvent-catalyst metal content.

76. A femoral head as recited in claim 69 wherein said diamond table is formed using CoCr as a solvent-catalyst metal.

77. A femoral head as recited in claim 69 wherein said diamond table presents a non-planar diamond load bearing and articulation surface.

78. A femoral head as recited in claim 69 wherein said interstitial spaces are filled with a metal.

79. A femoral head as recited in claim 69 wherein said interstitial spaces are filled with solvent-catalyst metal.

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